Land Surface Geo/Biophysical Variable Estimation from EO-1 Data and Validation

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Abstract— We present several algorithms in this paper for estimating a series of land surface geophysical and biophysical variables from two EO-1 (earth Observing-1) sensors: ALI (advanced land imager) and Hyperion. These variables include spectral reflectance from the atmospheric correction algorithms, broadband albedos converted from narrowband albedos, and leaf area index. The field campaign at Coleambally, Australia as part of the validation activities will also be described. ALI corresponds to the Landsat7/ETM+ sensor, its advantages for estimating these land surface variables over ETM+ will be demonstrated.

I. INTRODUCTION

Earth Observing-1 (EO-1) is the first satellite in NASA's New Millennium Program Earth Observing series. The EO missions will develop and validate instruments and technologies for space-based Earth observations with unique spatial, spectral and temporal characteristics not previously available.

EO-1 was launched on Nov. 21, 2000 with three advanced land imaging instruments on board: Advanced Land Imager (ALI), Hyperion (Hyperspectral Imager), and Atmospheric Corrector.

The ALI provides Landsat type panchromatic and multispectral bands. These bands have been designed to mimic six Landsat bands with three additional bands covering 0.433-0.453, 0.845-0.890, and 1.20-1.30 μm. The multispectral images have the resolution of 10 meters, while the panchromatic images 10 meters.

The Hyperion provides a high resolution hyperspectral imager capable of resolving 220 spectral bands (from 0.4 to 2.5 μm) with a 30 meter resolution. The instrument can image a 7.5 km by 100 km land area per scene.

The Atmospheric Corrector is the first space-borne sensor to provide water vapor content of the atmosphere specifically for increasing the accuracy of surface reflectance estimates through atmospheric correction. It has 256 bands covering .85-1.5 μm with the spatial resolution of 250m.

To evaluate the EO-1 data with respect to their ability to meet the needs for future Landsat-class observations at reduced cost and with enhanced quality and evaluate space-based imaging spectrometers for potential future scientific and applied uses, we have developed a series of algorithms for characterizing the atmospheric and surface conditions from EO-1 observations. Since the real EO-1 data are still under processing and analysis, only the algorithms will be described here and the results will be presented later in the talk.

II. ATMOSPHERIC CORRECTION

Atmosphere has significant effects on satellite imagery. Atmospheric effects in the clear-sky condition include molecular and aerosol scattering and absorption by gases, such as water vapor, ozone, oxygen and aerosols. Molecular scattering and absorption by ozone and oxygen are relatively easy to correct because their concentrations are quite stable over both time and space. The most disturbing and difficult components of atmospheric correction are to estimate both aerosol optical depth and water vapor content.

We will estimate the aerosol optical depth from ALI and Hyperion imagery directly. The estimation of water vapor content from Hyperion and AC will not be discussed here. The most popular method that has been used for correcting aerosol effects from several satellite systems is the so-called "dark-object" algorithm. However, if there is no dense vegetation canopies that are evenly distributed in the scene, the "dark-object" algorithms will generally fail. To overcome this limitation and various disadvantages of other algorithms, we have developed a new algorithm for general atmospheric and surface conditions and therefore suitable for operational applications [1]. The validation results [2]. showed that this method can accurately retrieve surface reflectance. The original algorithm was for Landsat7 ETM+ imagery, one of the examples [1] is shown in Fig.1. We have recently applied it to the hyperspectral imagery (AVIRIS), it works very well (Fig.2). We are applying this method to ALI and Hyperion imagery.

III. NARROWBAND TO BROADBAND ALBEDO CONVERSION

Land surface broadband albedo is a critical variable affecting the earth s climate. It has been well recognized that surface albedo is among the main radiative uncertainties in current climate modeling. If the surface is assumed to be a Lambertian, the retrieved surface reflectance of different

spectral bands are equivalent to surface spectral albedos. A following-up step is to convert these narrowband albedos to broadband albedos. Studies on the narrowband to broadband albedo conversions in the literature are based on either field measurements of certain surface types or the model simulations with a limited variation of inputs, and also primarily for calculating total shortwave broadband albedo. Based on extensive radiative transfer simulations, Liang [3] recently developed the conversion formulae of several sensors for calculating seven broadband albedos (total-shortwave, -visible and -near-IR, direct- and diffuse-visible and -near-IR), including ASTER, AVHRR, ETM+/TM, GOES, MODIS, MISR, POLDER, and VEGETATION. The validation results [4] showed that those formulae can accurately predict broadband albedos.

The same procedure has been applied to ALI. The resulting formulae are believed to be more accurate than ETM+ because of three more spectral bands available. The formulae for calculating three broadband albedos are given below:

$$
\begin{aligned}
R_{short} = \ & 0.3466r_1 - 0.1435r_2 + 0.2278r_3 + \quad (1) \\
& 0.0985r_4 + 0.0574r_5 + 0.2159r_6 + \\
& 0.0385r_7 + 0.1139r_8 + 0.0620r_9 - 0.0012
\end{aligned}
$$

$$
\begin{aligned}
R_{visible} = \ & 0.2812r_1 + 0.1248r_2 + 0.3592r_3 \quad (2) \\
& + 0.2353r_4
\end{aligned}
$$

$$
\begin{aligned}
R_{Near-IR} = \ & 0.2917r_5 + 0.2707r_6 - \quad (3) \\
& 0.0316r_7 + 0.2502r_8 + 0.2258r_9
\end{aligned}
$$

where r_i represents the ALI spectral reflectance, and R_{short}, $R_{visible}$ and $R_{near-IR}$ are three total shortwave, visible and near-IR broadband albedos. These formulae are linear, but the fittings are very good, with residual standard errors (0.00736, 0.001044 and 0.007437) and Multiple R-Squared values (0.9985, 1.0 and 0.9982)

IV. Estimating leaf area index

Leaf area index (LAI) is one of the key variables driving the ecological, hydrological, agricultural and climatic models. A number of algorithms for estimating surface parameters have been published. The choice of available algorithms spans from simple statistical empirical methods to complex physical radiative transfer modeling techniques. The statistical algorithms are easy to implement but site specific. The physical algorithms explicitly handle the physical processes and therefore offer potential for improvement through introducing more accurate inputs or refinement of parameterizations of each physical process.

The statistical algorithms primarily use multispectral information, such as vegetation indices, while most physical algorithms reply on multiangular information based on optimum inversion algorithms. It is important to explore physical inversion algorithms based on spectral information. This has been demonstrated in the derivation of the MODIS LAI/fAPAR products [5].

we have developed a hybrid algorithm that combines the physical simulations with nonparametric statistical methods. This method is based on extensive radiative transfer simulations and nonparametric statistical inversion methods with neural network and the projection-pursuit regression technique. The results will be shown later.

V. Field campaign at Australia

Coleambally Irrigation Area (CIA) is an agricultural site, which is part of the 1.5 billion dollar per year irrigation industry of southeastern Australia. Principal summer crops (November-April) are rice, soybeans, and Maine. Wheat, oats, and barely are grown over winter (May-October). A series of EO-1 data have been acquired over CIA site during the summer to capture the crop growing cycle. In early February, 2001, we conducted a field campaign over CIA. Surface spectral reflectance and broadband albedos were measured with the satellite overpass on Feb. 3. LAI measurements were conducted in the following days. These ground measurements are extremely valuable to validate our algorithms and products. Several other field campaigns over CIA were also conducted with different objectives and measurements.

VI. conclusion remarks

Our algorithm development mainly focus on the use of the spectral information to estimate surface bio/geophysical variables. Since ALI has three more bands than ETM+, we expect that these algorithms will work much better over ALI imagery than over ETM+ imagery. The preliminary results and their validations will be presented later.

VII. Acknowledgments

References

[1] S. Liang, H. Fang, and M. Chen, "Atmospheric correction of ETM+ land surface imagery: I. Methods," *IEEE Trans. Geosci. Remote Sens.* submitted.

[2] S. Liang, H. Fang, J. Morisette, M. Chen, C. Walthall, C. Daughtry and C. Shuey, "Atmospheric correction of ETM+ land surface imagery: II. Validation and Applications" *IEEE Trans. Geosci. Remote Sens.* submitted.

[3] S. Liang, "Narrowband to broadband conversions of land surface albedo: I. Formulae," *Remote Sens. Environ.* vol. 76, pp. 213-238, May, 2001.

[4] S. Liang, C. Shuey, H. Fang, A. Russ, C. Walthall, C. Daughtry, and R. Hunt, "Narrowband to broadband conversions of land surface albedo: II. Validation," *Remote Sens. Environ.* to be submitted.

[5] Y. Knyazikhin, J. Martonchik, R. Myneni, D. Diner, and S. Running, Synergistic algorithm for estimating vegetation canopy leaf area index and fraction of absorbed photosynthetically active radiation from MODIS and MISR data, *J. Geophys. Res.* vol. 103, pp. 32257-32275, 1998.